

Breeding ecology of the Northern Boobook *Ninox japonica totogo* in central Taiwan

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Introduction

The Brown Hawk Owl complex *Ninox scutulata*, also known as the Brown Boobook (King 2002), is widely distributed in East Asia, from south-eastern Siberia, North Korea, Japan, Taiwan and the Philippines to the Moluccas and the Lesser Sundas (del Hoyo *et al.* 1999, König *et al.* 1999). Such a wide range has produced phenotypic variation between populations, including in size, morphs and migration status. Recent authors have recognised 11 (del Hoyo *et al.* 1999) or 13 (König *et al.* 1999) subspecies, but King (2002) analysed sonagrams of territorial songs from 11 subspecies and separated the entire complex into three distinct species: 'Brown Boobook' *N. scutulata*, 'Chocolate Boobook' *N. randi* and 'Northern Boobook' *N. japonica*. Accordingly, the taxonomic designation of this owl in the Far East is *N. japonica*. This species consists of two subspecies: *N. j. japonica*, a summer visitor in northern regions such as Japan and Korea, and *N. j. totogo*, a resident of the southern regions. King (2002) also indicated the extreme paucity of research on the entire species complex.

The type locality of *N. j. totogo* is Lanyu, a tiny offshore islet located 50 km south-east of Taiwan. Although a breeding population of *N. j. totogo* on this islet has been known for many years (Severinghaus 2007), the resident status of *N. japonica* in Taiwan has been the topic of long and lasting debate. The species in Taiwan was originally treated as a migrant or transient (Hachisuka & Udagawa 1951, Wang *et al.* 1991), whereas later literature considered it a resident because it was found to occur throughout the year (Mees 1970, Dickinson 2003). Recent literature has proposed the occurrence of both resident and migratory populations in Taiwan (Brazil 2009, Severinghaus *et al.* 2010). However, breeding records of the species in Taiwan were not published until 2010, when Tseng & Lin (2010) and Severinghaus *et al.* (2010) separately reported partial information from their occasional observations on the breeding behaviour of this owl. Nevertheless, breeding by this owl in East Asia has never been documented in detail.

In this study, we provide: (1) robust evidence for the occurrence of a breeding population in Taiwan (*N. j. totogo*); (2) a first quantitative report on the breeding ecology of this species; (3) basic morphometrics of these breeding individuals; and (4) a comparison of ecological and morphological differences between the summer visitors (*N. j. japonica*) and residents (*N. j. totogo*) in Far East Asia.

Methods

Study area and nest-site search

The study area is located in central-western Taiwan, within latitudes 23°55'N and 24°03'N and longitudes 120°44'E and 120°53'E. The majority of the landscape in this region is subtropical hardwood forest at 70–700 m elevation, with a mosaic of villages and cultivated lands. The Northern Boobook primarily inhabits densely vegetated woodland, and its tree-cavity nest-sites are very difficult to locate. From 1999 to 2009, every suspected or confirmed pair was intensively followed in the period 1 January to 30 April, a time when the pairs are very active and the frequency of breeding calls and copulation could be recorded by directly approaching the pairs using spotlights. The nest holes were found by tracing the routes of male and female owls and by locating the source of calls. The route-tracing method was based on the observation that if one individual (usually the female) disappeared from sight, this could indicate preparation for egg-laying involving staying near or in the

nest-site. The nest-site could then be found by tracing the routes—the direction in which the owls flew after sunset and before sunrise—taken by male and female owls at the time of pair-formation. The call-location method was based on the observation that the owls began calling at sunset, usually initially near the nest-site. We located the first calls of the owls and approached their probable location. This method provided excellent opportunities to find nests.

Landscape structure of the nesting site and breeding phenology

After the nest was found, we identified the tree to species and measured its diameter at breast height (DBH). A circle with a radius of 500 m, which was considered suitable for the territorial extent of a small owl (e.g. Pande *et al.* 2007, Santhanakrishnan *et al.* 2011), was plotted around the nest-site. The landscape composition (as a percentage of the total area) within this region was estimated from an aerial photograph. The following categories of landscapes were identified: primary forest (also termed original forest) (PF), secondary forest (SF), artificial forest (MF), orchards (OC), betel nut palms (BP), trees along streets (ST), roads (RD), buildings (BD) and urban parks (UP).

Multiple direct visits to the nests were conducted to confirm the clutch size and brood size for every breeding attempt. A video camera attached on an elongated aluminium pole with mobile monitor was used to record the subsequent stages. We marked the egg(s) to estimate the incubation period in each nest. When the nestlings were approaching fledging, we visited the nest-site every day to confirm fledging date and number of successfully fledged nestlings. A nest that produced at least one fledgling was recorded as successful. We observed and recorded the activities of young and parents every 3–7 days until they dispersed from the nesting area.

Morphometrics

Morphological measurements of the adults were taken during the incubation or early nestling periods. Adults were directly caught by hand or hand-net when inside the nest holes. The length of bill (from tip to cere), head (from bill-tip to end of skull), wing chord, tail and tarsus were measured to the nearest 0.1 mm with digital calipers, and the body mass to 0.1 g with an electronic scale. The individuals were banded with an aluminium ring and a coloured ring for individual identification. Males and females were identified by observing their mating, guarding and incubating behaviours (males do not incubate). All measurements were compared between males and females with a nonparametric Mann-Whitney U test.

Results

Nest-sites and nest-trees

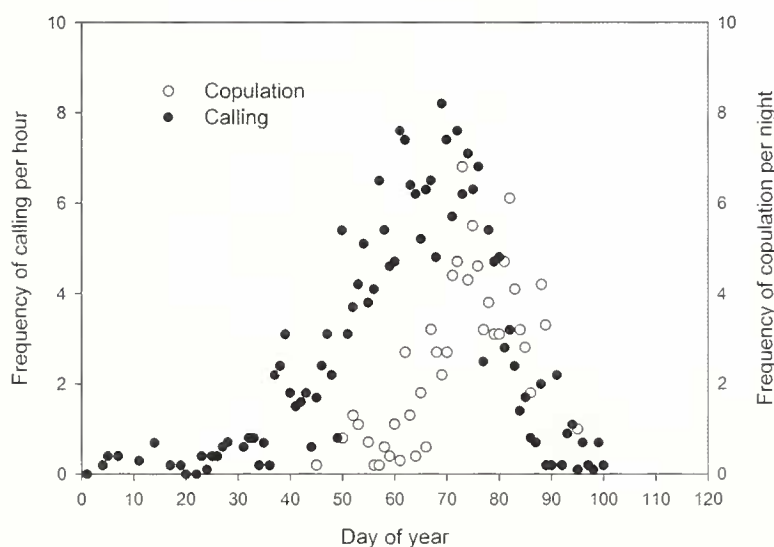
Ten nests of the Northern Boobook were recorded during the study period, with no nesting site being re-used. Eight were located in a relatively natural environment, at altitudes of 350–700 m. The other two nests were found in suburbs, both at 70 m elevation. The landscape structure around the rural nests was dominated by secondary forest (range 35–95%, mean 75%), followed by artificial forest (range 5–25%, mean 13%). In contrast, the suburban nests were surrounded by a landscape including 57–58% of man-made structures (including roads and buildings) (Table 1). Six species of nest-tree were identified (Table 1).

Table 1. Data on ten nests of Taiwanese Northern Boobooks: year, location, elevation, nest-tree species, nest-tree diameter at breast height (DBH), and landscape composition. For landscape composition abbreviations see Methods.

No.	Year	Location	Elevation(m)	Nest tree	DBH (cm)	Landscape composition (radius 500 m) (%)									
						PF	SF	MF	BP	OC	ST	UP	BD	RD	
1	1999	Dakeng	380	<i>Machilus zuihaensis</i>	50		95	5							
2	2000	Yuchi	365	<i>Cinnamomum campharo</i>	48	60	35	5							
3	2002	Yuchi	700	<i>Helicia formosano</i>	55		48	25	25				2		
4	2004	Wufeng	375	<i>Helicia formosana</i>	70		88	12							
5	2005	Wufeng	350	<i>Cinnamomum camphara</i>	50		80	15	5						
6	2006	Wufeng	375	<i>Machilus zuihaensis</i>	62		80	15		5					
7	2006	Wufeng	415	<i>Aluerites fardii</i>	50		90	10							
8	2006	Wufeng	400	<i>Aluerites fardii</i>	45		85	15							
9	2008	Nantou city	70	<i>Eucalyptus robusta</i>	77						20	22	33	25	
10	2009	Nantou city	70	<i>Melaleuca leucadendra</i>	60						21	22	33	24	

Behaviour prior to egg-laying

Male Northern Boobooks began calling and occupying territories from January to February. The pair-bond formed from mid-February to early March. During this period the male and female were very vocal and usually moved about together. Copulation was observed at this stage. The frequencies of calling and copulation showed the same pattern, which increased before and decreased after egg-laying. Both behaviours reached their peak at around 11 March. However, copulatory behaviour was also observed at the incubation stage (Figure 1).

**Figure 1.** Frequency of calling and copulation in Taiwanese Northern Boobook during the breeding season. Data combined from the ten nests during the ten years.

Breeding phenology

Eggs were laid from 16 March through April, and the mean first egg-laying date was 28 March \pm 8.8 days. Mean clutch size was 3.2 ± 0.4 (range 3–4). Mean incubation period was 26.8 ± 1.8 days (range 25–31), and the eggs were incubated only by females. The nestlings hatched between 12 April and 7 May, and the hatching rate and brood size were $80.8 \pm 22.9\%$ (33–100%) and 2.6 ± 0.8 (1–4 chicks) respectively. Mean nestling period for successful nests ($n=9$) was 25.9 ± 1.1 days (range 25–28). Mean number of fledglings in all nests was 2.1 ± 1.0 , and the fledgling success rate was $86.7 \pm 32.2\%$ (Table 2). In the unsuccessful nest, four young drowned during the nestling period due to heavy rain. Most fledglings appeared in May, and the post-fledging period extended from mid-July through to late August.

Morphology of adults, eggs and nestlings

Ten pairs of adults were measured during the breeding period. No significant differences were found between adult males and females (Table 3). The eggs were $20.2 \pm 0.6 \times 18.2 \pm 0.4$ mm, with an average mass of 20.4 ± 1.2 g ($n=13$). Mean body mass of nestlings at ages 1, 5, 10, 15 and 20 days was, respectively, 16.8 ± 1.0 g ($n=6$), 41.7 ± 4.9 g ($n=3$), 100.6 ± 11.6 g ($n=5$), 118.3 ± 7.4 g ($n=3$) and 143.6 ± 11.6 g ($n=5$) (Figure 2). The growth equation between ages 1 and 20 days was $y = 6.8602x + 14.232$ ($r^2=0.96$), where y was the body mass and x was the age in days (Figure 2).

Discussion

This study is one of the very few attempts to quantify some basic parameters in the breeding ecology of birds in the *Ninox scutulata* complex. The only previous work has been on the Japanese

Table 2. First egg-laying day (number = day of year) (FD), clutch size (CS), incubation period (IP), brood size (BS), hatching rate (HR), number of fledglings (NF), fledgling success rate (FSR), and nestling period (NP) for the ten *Ninox* nests in central Taiwan. The incubation period was recorded from one or two eggs. In all, 17 eggs were used to estimate the mean incubation period.

No.	FD	CS	IP (days)	BS	HR (%)	NF	FSR (%)	NP (days)
1	85 (26 Mar)	3	25	3	100	3	100	25
2	88 (29 Mar)	4	27, 31	3	75	3	100	26
3	95 (5 Apr)	3	25, 26	2	67	2	100	25
4	94 (4 Apr)	3	27, 28	3	100	3	100	28
5	80 (21 Mar)	3	26	3	100	2	67	27
6	75 (16 Mar)	4	28, 31	4	100	0	0	–
7	80 (21 Mar)	3	25	1	33	1	100	25
8	77 (18 Mar)	3	25, 26	3	100	3	100	26
9	95 (5 Apr)	3	26, 27	2	67	2	100	26
10	100 (10 Apr)	3	26, 27	2	67	2	100	25
Mean \pm SE	86.9 \pm 8.8	3.2 \pm 0.4	26.8 \pm 1.8	2.6 \pm 0.8	80.8 \pm 22.9	2.1 \pm 1.0	86.7 \pm 32.2	25.9 \pm 1.1

Table 3. Morphological data for breeding adult Taiwanese Northern Boobooks. M-W = Mann-Whitney.

Morphological character	Male (n=10)		Female (n=10)		M-W U test	P
	mean	SE	mean	SE		
Bill (mm)	13.1	1.0	13.6	1.4	41.5	0.253
All head (mm)	51.1	3.4	49.8	2.9	39	0.207
Wing chord (mm)	217.2	6.5	214.0	20.1	47.5	0.412
Tail (mm)	119.4	10.1	118.8	5.8	40.5	0.229
Tarsus (mm)	33.9	2.6	33.3	2.8	44.5	0.468
Body mass (g)	167.5	22.4	168.2	27.5	49	0.470
Wing/tail	1.83	0.16	1.79	0.13	39	0.207

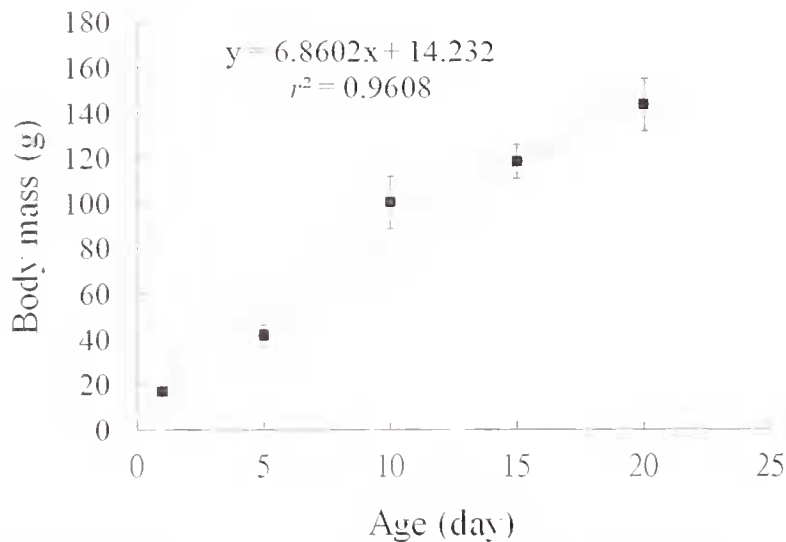


Figure 2. Mean body mass of nestling Taiwanese Northern Boobooks at 1, 5, 10, 15 and 20 days of age.

population of *N. j. japonica*, for which breeding data were briefly presented by Masuda (1974) and Oba (1996). A notable difference between the Taiwanese and Japanese populations is the marked difference in the timing of their breeding seasons. Whereas in Taiwan territory occupation and pair-formation begins in mid-February and mean first-egg date is 28 March, breeders in Japan do not arrive until April (Brazil & Yabuuchi 1991, Oba 1996), from which we deduce that the mean first egg-laying date cannot be earlier than 30 April. Moreover, the approximate length of the entire breeding season in Japan is only four months, a much shorter period than the seven months we have observed in Taiwan.

These differences raise the issue of the degree of morphological differentiation between migratory and resident birds in South-East Asia. A comparison of our morphometric data on *N. s. totego* with the measurements of *N. s. japonica* in King (2002) shows that the Taiwanese breeders have a slightly shorter wing chord (214.0 mm for males and 217.2 mm for females vs 220.8 mm for *N. s. japonica*) and slightly longer tail (119.4 mm for males and 118.8 mm for females vs 115.8 mm for *N. s. japonica*), a result consistent with the tendency of migratory birds to have a higher wing/tail ratio to facilitate their over-water dispersal (Averill 1920, Yong & Moore 1994). This suggests that the migratory and resident birds in Taiwan and South-East Asia might have developed a degree of local adaptation and genetic differentiation. The species diversity of *Ninox* owls in the Far East might therefore still be underestimated, and this needs to be tested with genetic markers in future.

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